

Verizon Airfone Response to Air-to-Ground Licensing Scenarios Under Consideration by the FCC

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Contents

Executive Summary	1
I. Introduction	2
A. Scenario #1: 2.5 MHz / 1.5 MHz Exclusive Licenses	3
B. Scenario #2: Two Overlapping 2.5 MHz Licenses	3
C. Scenario #3: One Exclusive 4 MHz License	4
II. Need for 3 MHz of Exclusive Spectrum	5
III. Impact on User Experience	6
A. Study Assumptions	6
B. Study Results	9
IV. Band Sharing Requirements	12
A. Scenarios #1 and #3	13
B. Scenario #2	13
1. What would be the required separations between ground stations?	13
2. Would directional antennas be required on the aircraft?	15
3. Would tracking software be required to enable each service provider to know what the other service provider is doing?	16
4. Are there limits on what modulation schemes could be employed? Can CDMA or OFDM be employed under any of the three scenarios? Can two CDMA or two OFDM systems share the spectrum on an overlapping basis? Can a CDMA system and an OFDM system share the spectrum on an overlapping basis?	16

5. Would reverse banding be required?	16
6. Would cross polarization be required?	17
7. Would special equipment be required on the aircraft or on the ground? If so, what are the costs of this equipment? Does the equipment employ “off-the-shelf” technology that is available today?	17
8. What rules would the FCC need to adopt to facilitate sharing?	18
9. How much coordination would be required between the two ATG licensees?	19
V. Impact on Future Growth and Service Evolution	19
VI. Treatment of Incumbent Licensee	20
VII. Conclusion	20

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Executive Summary

Verizon Airfone has consistently maintained in this proceeding that there is only sufficient capacity for a single viable broadband service provider in the 4 MHz of Air-to-Ground (“ATG”) Service spectrum. Staff of the Federal Communications Commission (“Commission” or “FCC”) has asked Verizon Airfone (“Airfone”) to comment on three different scenarios for licensing this spectrum:

- Two exclusive licenses to be auctioned – one with 2.5 MHz of paired spectrum and the other with 1.5 MHz of paired spectrum;
- Two shared licenses to be auctioned with 2.5 MHz of paired spectrum each (resulting in 40% spectral overlap); and
- A single 4 MHz paired license to be auctioned.

As an initial matter, the scenarios under consideration by the FCC Staff do not appear to take into account Airfone’s rights as the incumbent licensee. Staff has suggested that under one or more of these scenarios, Airfone might have to relocate its current narrowband operations to a smaller portion of the band (i.e., the lower 2 x 0.75 MHz). However, it is not clear how Airfone’s existing operations would be protected under each of the three scenarios. It is imperative that the Commission protect Airfone’s incumbency rights for as long as it operates in the band. The attached legal memorandum sets forth an analysis of Airfone’s rights as an incumbent in the band.

As Verizon Airfone explains here, only the third scenario (a single 4 MHz paired license), represents a workable option for providing broadband ATG service. The first scenario fails to provide adequate spectrum to accommodate a broadband system, given the guard band requirements indicated by leading technology developers. Airfone notes that this scenario can be accommodated if 3.0 MHz of paired spectrum is made available for the “broadband” ATG provider.

As Verizon Airfone has demonstrated in several detailed technical analyses and reports, the second scenario fails to permit the provision of broadband service due to significant harmful interference that would be caused by overlapping two ATG systems. The Commission would need to adopt extensive and inflexible sharing rules just to minimize the amount of interference experienced by ATG licensees. And, even if such rules were adopted, interference among competing ATG service providers would substantially limit the level of service provided to ATG customers. Under some situations, debilitating interference among ATG base stations and from Navy radar

systems would preclude service entirely, especially in areas around major airports and along both coasts of the United States.

Importantly, the debilitating interference that would be experienced around airports would prevent Airfone (or any other ATG provider) from providing service all the way from takeoff to landing (i.e., “deck-to-deck” service). Deck-to-deck service is an important part of the service that Airfone provides today to its ATG customers, and it is vitally important to airline officials and law enforcement officers that use commercial ATG services for critical communications links. It is also important to private and government general aviation customers. It is absolutely critical that the Commission not adopt rules that would impede the delivery of these services.

If the Commission were to adopt either of the exclusive licensing scenarios (modified to include appropriate guard bands), then a feasible broadband service is achievable. The data provided here demonstrates that an exclusive licensing scenario is the only way to ensure the delivery of a high quality broadband ATG service to consumers. The authorization of exclusive licenses will also allow licensees considerable flexibility in developing and deploying their network and making future changes to keep up with technological innovation. A band-sharing arrangement would require an inflexible regulatory structure that would require the Commission to dictate technology selection, location of base station sites, and various operating rules and procedures.

In sum, Verizon Airfone has demonstrated that any sharing of the ATG spectrum will exclude the provision of broadband services. Sharing of the band will lead to significant harmful interference between ATG providers, require considerable provider coordination and Commission oversight, and necessitate a rigid regulatory framework that will inhibit, if not preclude, any flexibility for initial broadband operations as well as future innovation in the band. Additionally, the licensing scenarios under consideration by the FCC Staff fail to adequately address how Verizon Airfone’s incumbency rights will be protected.

I. Introduction

The Commission has initiated a proceeding to review its rules governing the provision of ATG service in the 800 MHz band, including an assessment of the opportunities for promoting innovative service offerings in the band.¹ Airfone and others have urged the Commission to modify its rules to permit the provision of broadband ATG services, noting that there is a significant demand for such services and the Commission’s current rules prevent licensees from providing them.²

¹ See *Amendment of Part 22 of the Commission’s Rules To Benefit the Consumers of Air-Ground Telecommunications Services*, WT Docket No. 03-103, Notice of Proposed Rulemaking (“*ATG NPRM*”), rel. Apr. 28, 2003.

² See Verizon Airfone’s Comments on Notice of Proposed Rulemaking, WT Docket No. 03-103, filed Sept. 23, 2003; see also Comments of Qualcomm Incorporated, WT Docket No. 03-103, filed Sept. 23, 2003.

On August 24, 2004, representatives of Airfone met with representatives of the FCC's Wireless Telecommunications Bureau and Office of Engineering and Technology (collectively "FCC Staff") to discuss the pending proceeding. At that meeting, FCC Staff presented Airfone with various scenarios under consideration by the Commission in this proceeding for delivering ATG service in the 800 MHz band. These are described briefly in the following pages.

A. Scenario #1: 2.5 MHz / 1.5 MHz Exclusive Licenses

Two separate licenses would be issued, each providing the licensees with "exclusive" rights to operate in their respective bands. (See Figure 1). The A block would include 849.00-850.25 MHz paired with 894.00-895.25 MHz. The B block would include 850.25-851.00 MHz paired with 895.25-896.00 MHz. The incumbent licensee in the band, Verizon Airfone, would be required to consolidate all of its current operations into the 850.25-851.00/895.25-896.00 MHz band.

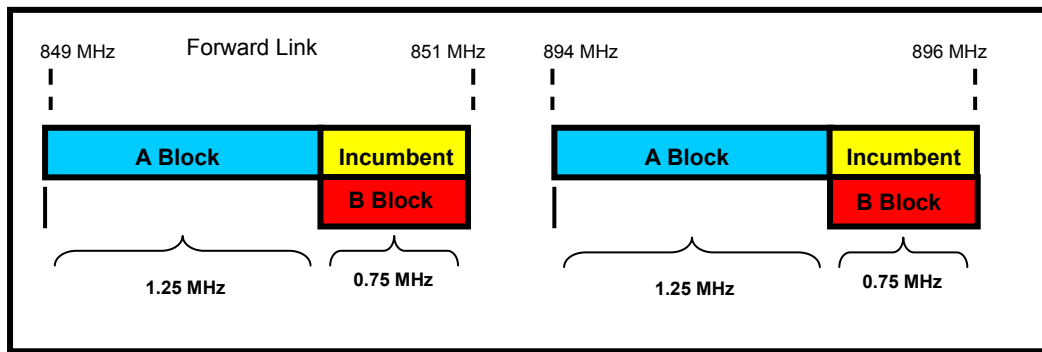


Figure 1

B. Scenario #2: Two Overlapping 2.5 MHz Licenses

Two separate licenses would be issued, each encompassing 2.5 MHz and each requiring a portion of the spectrum to be shared. (See Figure 2). The A block would include 849.00-850.25 MHz paired with 894.00-895.25 MHz. The B block would include 849.75-851.00 MHz paired with 894.75-896.00 MHz. The incumbent licensee in the band, Verizon Airfone, would be required to consolidate all of its current operations into the 850.25-851.00/895.25-896.00 MHz band.

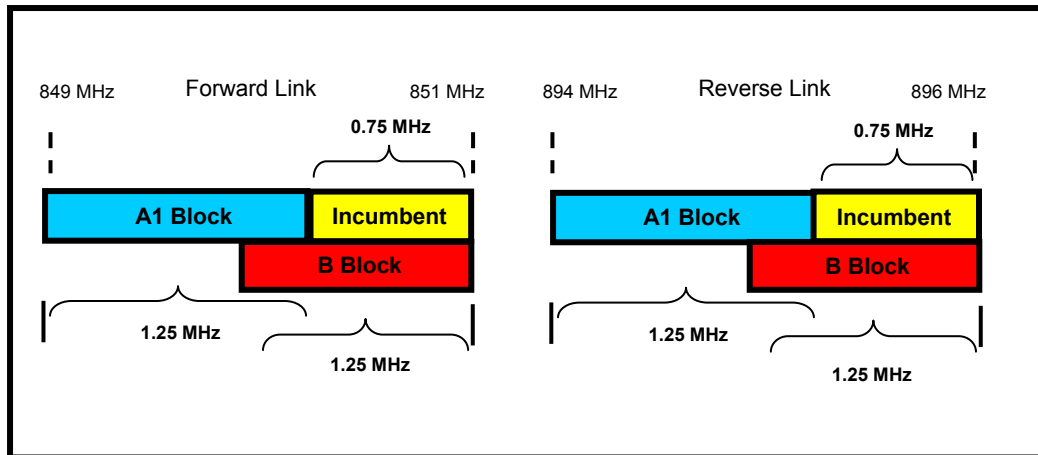


Figure 2

C. Scenario #3: One Exclusive 4 MHz License

One license would be issued, encompassing the entire 4 MHz of available spectrum; 849.00-851.0 MHz paired with 894.00-896.00 MHz. (See Figure 3). The incumbent licensee in the band, Verizon Airfone, would be required to consolidate all of its current operations into the 850.25-851.00/895.25-896.00 MHz band.

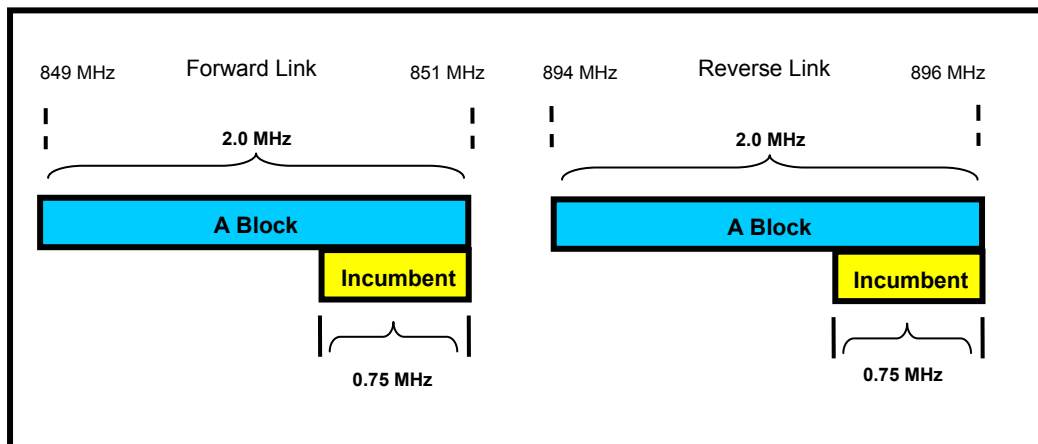


Figure 3

Airfone has been asked to provide the Commission with information regarding how each of these possible scenarios would impact the ability of a licensee to provide a viable ATG service in the 800 MHz band. In particular, the Staff seeks input on how each scenario would affect the user experience and what technical, operational, and regulatory requirements would be necessary to facilitate deployment of ATG service under each scenario.

II. Need for 3 MHz of Exclusive Spectrum

At the outset, Airfone notes a serious concern with some of the scenarios under consideration by the FCC Staff. Information is sought on three scenarios, but only one of these provides sufficient spectrum for provision of a broadband ATG service. While advanced technologies such as Code Division Multiple Access (“CDMA”) and Orthogonal Frequency Division Multiplexing (“OFDM”) specify channel sizes of 2.5 MHz (2 x 1.25 MHz), a license block greater than 2.5 MHz is necessary to accommodate required guard bands. As demonstrated by Qualcomm and Flarion, the minimum required block size is 3.0 MHz (2 x 1.50 MHz).³

Consequently, to adequately accommodate the provision of broadband ATG services utilizing either CDMA or OFDM technology, we believe it is necessary for the FCC to modify its proposed scenarios to incorporate license blocks that are 3.0 MHz, and not 2.5 MHz, in size. In particular, Scenario #1 should be modified to specify one 3.0 MHz (2 x 1.50 MHz) exclusive license and one 1.0 MHz (2 x 0.50 MHz) exclusive license. (See Figure 4).

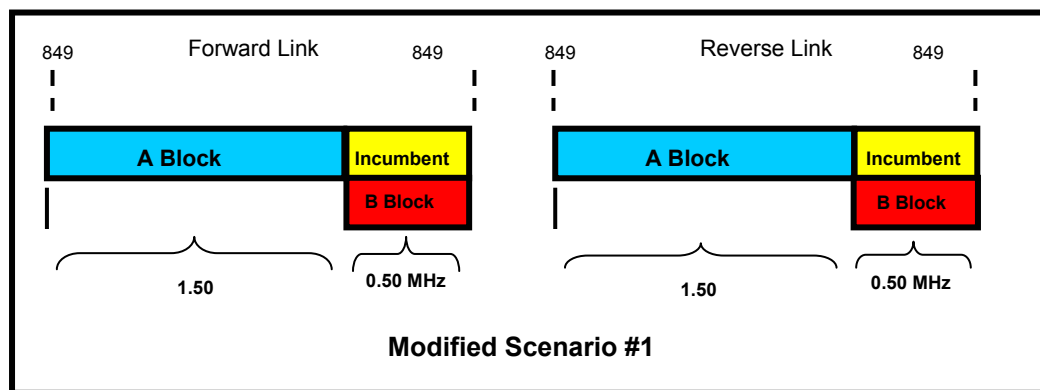


Figure 4

Even Scenario #2, which Airfone has shown would result in substantial interference and diminished service capability, should, for analytical purposes, be evaluated under the assumption that guard bands would be required at the band edges to accommodate broadband technologies without the threat of harmful interference to and from adjacent bands. (See Figure 5). Airfone has incorporated such a guard band requirement in its analyses of the various scenarios described in this report. For example, in conducting its assessment of Scenario #2, Airfone has included a “60% overlap” assumption, rather than the 40% overlap recommended by the Staff.

³ See *gen.*, Ex Parte Letter of Flarion Technologies Inc., in response to *ATG NPRM*, filed Sept. 2, 2004; see also Ex Parte Letter of Qualcomm Incorporated, in response to *ATG NPRM*, filed Sept. 3, 2004.

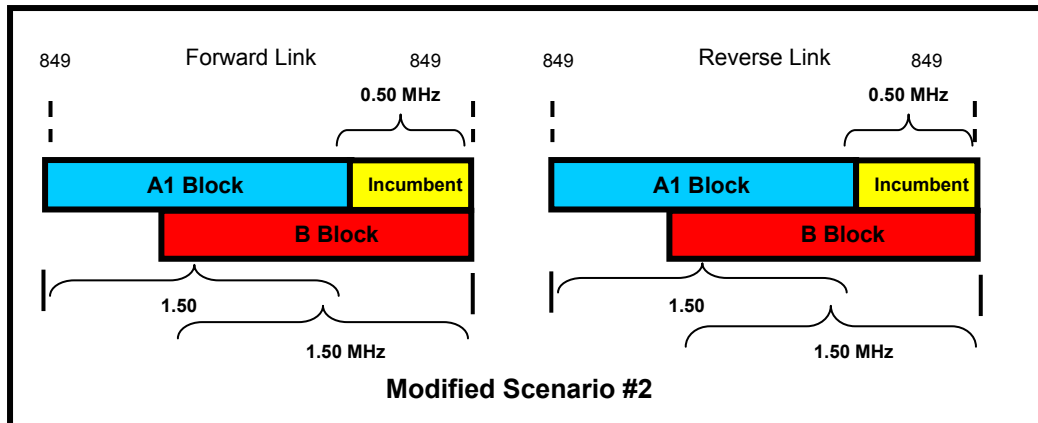


Figure 5

III. Impact on User Experience

In prior submissions to the Commission, Airfone has noted that a band-sharing arrangement that results in harmful interference to ATG systems will necessarily impact the types and quality of services that can be offered.⁴ In response to these concerns, the Staff has asked Airfone to provide information regarding how each of the three scenarios described above would impact user experience.

A. Study Assumptions

For the purposes of this analysis, we have been asked to assume that there are 15 simultaneous users per airplane and three airplanes present in a single sector at any one time. Airfone has noted to the Staff that these assumptions do not reflect the real-world situations in which a broadband ATG network must operate, and has urged the Staff to modify its assumptions to better reflect real-world conditions.⁵ In designing its current network, Airfone assumes that there are ten planes present in each sector at any given time. In some cases, there may be more than ten. The attached map (Figure 6) illustrates the air traffic around Chicago at a particular instant in time on August 24, 2004. The map depicts three 120 degree sectors and shows a radius of 200 miles. As can be seen, there are significantly more than three planes in each of the three sectors.

⁴ See Ex Parte Presentation of Verizon Airfone, in response to *ATG NPRM*, filed Apr. 12, 2004 (“*Airfone Apr 12th Ex Parte*”); see also Ex Parte Presentation of Verizon Airfone, “*Coexistence Analysis for Multiple Air-to-Ground Systems*,” technical paper by Dr. Anthony A. Triolo and Dr. Jay E. Padgett, Telcordia Technologies, Inc., in response to *ATG NPRM*, filed Jun. 3, 2004 (“*Airfone Jun 3rd Ex Parte*”) at 26-30 and 46-51.

⁵ See Ex Parte Letter of Verizon Airfone, in response to *ATG NPRM*, filed Aug. 24, 2004 (noting the need to accommodate actual air traffic expected around major airports) (“*Airfone Aug 24th Ex Parte*”).

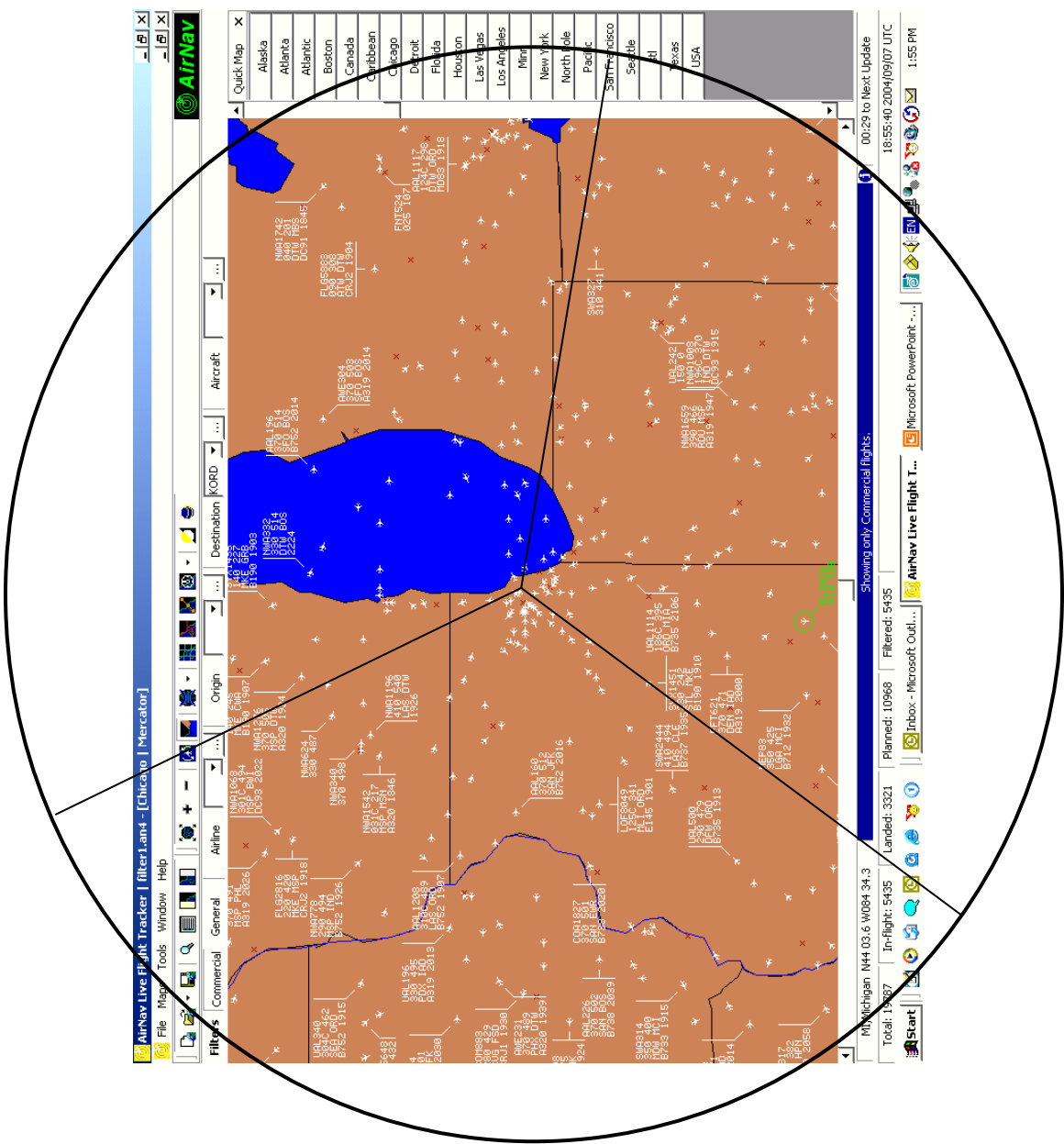


Figure 6

In its own traffic studies, Airfone assumes ten (and not 15) users per airplane. Importantly, this does not mean that there are only ten customers engaged in an active communications session with the network. Every passenger could, theoretically, be “on line.” It simply means that there are ten users that are actively sending and/or receiving data to/from the network (e.g., downloading and reading web pages) at a given point in time. While this number will obviously vary, Airfone has found that ten represents a reasonable average. In the analysis presented here, both sets of assumptions (15 users/airplane with 3 airplanes/sector and 10 users/airplane with 10 airplanes/sector) are evaluated.

As previously demonstrated, Airfone commissioned Telcordia Technologies, Inc. to perform a comprehensive interference analysis (including a detailed Monte Carlo analysis) to determine the throughput reduction that would be experienced by an aircraft if a second reverse-banded system (as proposed by AirCell) were operating within the same band.⁶ The assumptions used for the simulation were as follows:

- Base station output power of +43 dBm
- Base antenna gain of 15 dBi with up-tilt of 5°.
- Aircraft directional antenna with vertical gain of +6 dBi (0°).
- Base station radio range of 240 miles.
- 4,000 aircraft were assumed to be distributed uniformly over the continental United States, with the exception that higher density is assumed near the airports. This number was a conservative estimate of the number of ATG-equipped flights (commercial and general aviation) over the United States at peak hour. The number of aircraft in the air at peak hours as reported by AirNav Software’s *Flight Tracker 3* system is approximately 6,000. With a market penetration (total from all systems) of 66%, this yields 4,000 aircraft.
- Two CDMA 1xEV-DO systems present with the ground-to-air band of system 1 and the air-to-ground band of system 2 in the low-band (i.e., 849-851 MHz), and the air-to-ground band of system 1 and the ground-to-air band of system 2 in the high-band (i.e., 894-896 MHz).
- The two systems were assumed to be 40% overlapped in frequency (brick-wall filters around the signal) for the first simulation. This assumption is very optimistic, since the spectral occupancy of commercial CDMA systems is 1.5 MHz, including guard bands. Consequently, a second simulation was run with peak market penetration for the interfering carrier and 60% spectral overlap to determine the mean “to-the-seat” throughput.⁷

⁶ *Airfone Jun 3rd Ex Parte* at 44-51.

⁷ As discussed above, the need for guard bands to accommodate broadband technologies would result in a 60% overlap for the band-sharing proposal (Scenario #2).

- Base stations of system 1 (the victim system) were placed at locations where Airfone's actual legacy base stations are currently located.
- Aircraft belonging to system 1 employed a 6-beam switched-beam antenna system which selects the beam with the highest signal to interference plus noise ratio (SINR) over which to communicate.
- System 1 base stations were configured as 3-sector sites using antenna patterns from commercially available base station antennas.
- Path loss from ground-to-air and aircraft to aircraft was assumed to be free-space.
- All aircraft were assumed to be flying at 35,000 feet.
- 75% system loading was assumed.
- Transmit power from system 2 aircraft was assumed to be a random variable (due to power control) with an exponential distribution in dBm (reflecting the underlying assumption that aircraft are distributed uniformly in a disk around system 2 base stations). Two maximum power levels were assumed, one representing a low data rate reverse link (aircraft-to-ground) with 33 dBm transmitted ("low-power" case) and the other representing a high data rate reverse link with 43 dBm transmitted ("high-power" case). The average power is 3 dB less than the maximum.
- Aircraft of system 2 were assumed to have omni-directional antennas.
- Base station to base station interference was neglected.

B. Study Results

The results of Telcordia's analysis demonstrate that the use of a band-sharing arrangement, such as those proposed by AirCell and Boeing, would clearly have a significant negative impact on the level of service experienced by ATG customers.⁸ The

⁸ Boeing's latest proposal is not supported by communications theory. In its submission of August 26, 2004, Boeing suggests that a forward link data rate of 64 Mbps per sector could be provided over a 1.25-MHz channel at a distance of 160 km, with a total base station EIRP of 640 watts (slides 5 and 7). Boeing implies that this will be accomplished using 64 "channels" of 1 Mbps each, with 10 watts of base station EIRP assigned to each channel, but does not explain how this would be achieved. Importantly, what Boeing is suggesting violates the Shannon bound, a basic limit on the rate of information transmission over a given bandwidth that is well-known to communications engineers. The minimum signal-to-interference plus noise ratio required by the Shannon bound can be expressed as $SINR = 2^{R/W} - 1$ where R is the bit rate and W is the transmission bandwidth. With $R/W = 64/1.25 = 51.2$, the signal to interference plus noise ratio is $SINR = 2.6 \times 10^{15}$ or about 154 dB. For a 1.25-MHz channel the thermal noise floor is -113 dBm plus the receiver noise figure. If 3 dB is allowed for the noise figure and there is assumed to be no interference, then the received signal power must be $-110 + 154 = 44$ dBm, even if the receiver operates right at the Shannon limit. For a 160-km distance, the

results of the Monte Carlo simulation are shown in Figure 7. The graph summarizes the per sector throughput performance (with 40% spectral overlap) for the simulated network with two types of interfering aircraft and various levels of market share allocated to the interfering network. As previously noted, the two types of interfering aircraft are “low-power” (33 dBm max power) and “high-power” (43 dBm max power). As the graph illustrates, the throughput degradation that would be experienced by system 1 increases as the interfering network (system 2) gains market share.

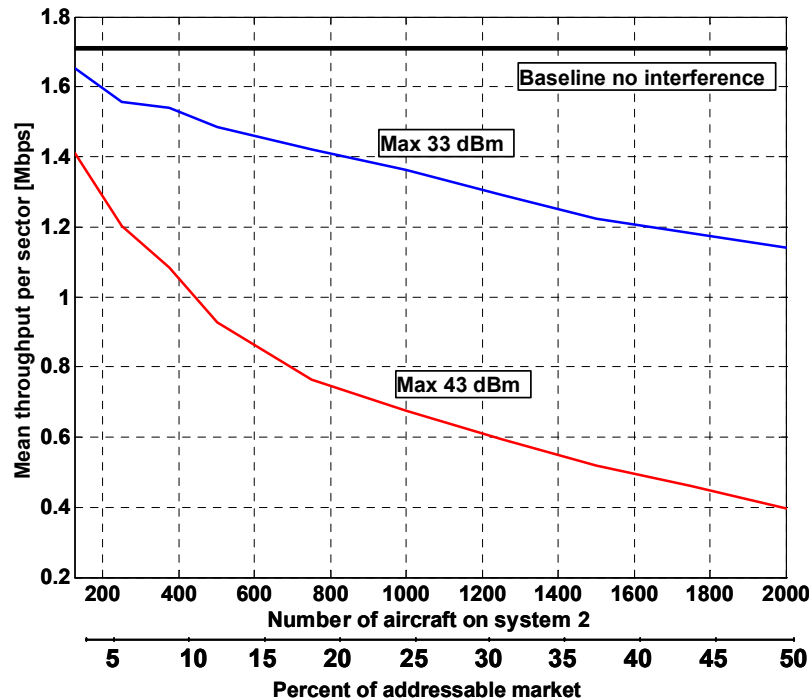


Figure 7: *Throughput degradation with cross-duplexed interfering system present overlapped by 40%.*

There is a strong demand for higher data rate services, and it must be assumed that operators will design their networks to accommodate such services. Higher data rates require higher power transmissions. As a result, the “high-power” case reflects the more probable case of interference between aircraft. As would be expected, and as seen in Figure 7, the degradation is greater when the interfering aircraft are allowed to transmit at higher power.

free space path loss is about 135 dB at 850 MHz, which means the base station EIRP must be $44 + 135 = 179$ dBm, or 149 dBW. This is 7.94×10^{14} , or **794 trillion watts**. Boeing’s claims therefore are unsupportable within the framework of known science.

To calculate the effective “to-the-seat” data rate available to the user, the mean throughput per sector shown from the graph is divided by the total number of concurrently active seats per sector (airplanes per sector times seats per airplane with active users), and then multiplied by an “oversubscription” or “overbooking” factor. This factor is a statistical multiplexing gain that reflects the fact that user demand for high-speed data is bursty. For example, after loading a web page, a user will require some time to absorb it, and during this time the user’s data connection is idle. Thus, when demanding a download, the apparent data rate experienced by the user is higher than the average rate per seat (capacity divided by number of users). An oversubscription factor of 5 is assumed here.⁹

Information provided by Qualcomm indicates that the total mean forward link throughput for the “no interferers” case would be 2.2 Mbps per sector. However, for the purposes of this analysis, we are using a more conservative figure of 1.7 Mbps per sector, based on published simulation results.¹⁰ Assuming this value, as well as three airplanes per sector and 15 active users per airplane, then the average rate per user is $1.7 \text{ Mbps} \div 45 = 37.8 \text{ kbps}$. Multiplying by the oversubscription factor of 5 gives an apparent rate to the user of 189 kbps. Table 1 provides the results of similar calculations for both the “no interferers” and the “high-power interferers” cases based on various modeling assumptions.

	3 Aircraft Per Sector With 15 Users Per Aircraft	10 Aircraft Per Sector With 10 Users Per Aircraft
No Interferers	189.0	85.0
40% Spectral Overlap	44.5	20.0
60% Spectral Overlap	33.0	14.5

Table 1: *Effective available data rate to the seat (kbps) on the CDMA 1xEV-DO forward link with reverse-banded interference for the cross-country scenario (ignoring the base-to-base interference problem for areas near airports) compared to non-overlapping (“No Interferers”) scenario. “High-power” interference case is assumed. Note: 60% overlap is more realistic than 40% due to need for guard bands.*

From this analysis, one can conclude that the adoption of a band-sharing arrangement as opposed to an exclusive use arrangement would have a significant negative impact on the ability of a service provider to deliver higher data rate services. The “no interferers” case represents the average data rate one would expect where there is no band-sharing (Scenarios #1 and #3), while the “high-power interferers” case represents the maximum data rate one could expect to achieve if band-sharing were adopted (Scenario #2).

⁹ Based on information provided by Qualcomm, Inc.

¹⁰ *Airfone Jun 3rd Ex Parte.*

Importantly, this analysis does not include the impacts of base station to base station interference that would occur under a band-sharing arrangement (Scenario #2) using reverse-banding and would render the ATG service inoperable (i.e., 0 kbps).¹¹ To avoid such interference, the FCC would effectively need to limit operations near airports to a single provider. Indeed, Figure 6 illustrates the need to provide dense base station coverage around major airports like those in the Chicago area. As discussed in more detail in section IV.B.1, below, it also illustrates the difficulty of siting base stations that would not cause interference to each other under Scenario #2 while providing coverage to aircraft on the runways and to those approaching the airport along various well-defined flight paths in which the aircraft would be virtually in-line.

This analysis also does not include the harmful effects of interference from Navy radar systems that would be unavoidable under a reverse-banding arrangement.¹² These systems could cause debilitating interference along both coasts of the United States, again rendering the ATG service inoperable (i.e., 0 kbps).

Airfone's customers require a high level of service quality. For a broadband ATG service to be attractive in the marketplace and competitive with alternative services offered by Boeing or others, it must have a high degree of availability and provide data rates that support broadband applications. A band-sharing arrangement that results in a substantially reduced level of service, and in some cases no service at all, will clearly not promote a competitive broadband ATG market. Importantly, the debilitating interference that would be experienced around airports would prevent Airfone (or any other ATG provider) from providing "deck-to-deck" service. The provision of such service is important to Airfone's existing customers. Moreover, airline officials and law enforcement officers are increasingly using commercial ATG services and high quality service all the way to the runway is vital.¹³ It is absolutely critical that the Commission not adopt rules that would impede the delivery of these services.

IV. Band Sharing Requirements

Several schemes have been proposed to the Commission for sharing the 4 MHz of spectrum current allocated to the ATG service at 800 MHz. Some of these schemes may require special operating parameters to share the band. Consequently, the Staff asked Airfone to comment on any specific requirements that would facilitate band sharing under each of the scenarios described above.

¹¹ *Airfone Jun 3rd Ex Parte* at 9-10; *see also* Ex Parte Presentation of Verizon Airfone, in response to ATG NPRM, "Response to Recent AirCell Filings and Summary Comments on AirCell Proposals," technical paper by Dr. Jay E. Padgett, Telcordia Technologies, Inc., filed Aug. 17, 2004 ("*Aug 17th Response to AirCell*") at 5-6.

¹² *Airfone Jun 3rd Ex Parte* at 53; *Aug 17th Response to AirCell* at 7.

¹³ Additionally, there are other users such as private and government general aviation aircraft and commuter aircraft that will require deck-to-deck service.

A. Scenarios #1 and #3

Scenarios #1 (under a licensing scheme that would provide adequate guard bands) and #3 do not require ATG licensees to share the same spectrum. Consequently, unlike Scenario #2, they do not require special rules or requirements to facilitate band sharing. Specifically, they would not require any reverse-banding or cross-polarization arrangement. They would not require any special coordination requirements, tracking software, or special equipment on the ground or on the aircraft to facilitate sharing.¹⁴ They would not require a particular modulation scheme, nor would either of these scenarios limit in any way the modulation scheme that could be employed by an ATG licensee, or limit the natural evolution of ATG technology.

Scenario #1, which would permit the operation of two licensees in the ATG band but without requiring them to share spectrum, would not require the licensees to separate their respective ground stations by some minimum distance, as required under Scenario #2. As a result, licensees are afforded considerably greater flexibility, and no licensee is disadvantaged relative to the other.

B. Scenario #2 (Two Overlapping Licenses)

Scenario #2 would require two ATG licensees to share a significant portion of spectrum.¹⁵ As Airfone has explained, such a sharing scenario would significantly degrade the level of service provided to ATG customers, and in some circumstances, may preclude the service altogether. But even to achieve a reduced level of service, special requirements and/or procedures would be required to facilitate sharing. These are described in the following sections.

1. What would be the required separations between ground stations?

AirCell has made two different proposals, each of which proposes that band-sharing be accommodated via a reverse banding arrangement. Under such a scenario, the base stations of system #1 would transmit on the same frequencies used by system #2 for base station reception, and vice versa. This means that to avoid interference the base stations must be separated by a distance greater than their radio horizon, which is $d_{\min} = \sqrt{2}(\sqrt{h_1} + \sqrt{h_2})$ where d_{\min} is the radio horizon in miles and h_1 and h_2 are the

¹⁴ Verizon Airfone does plan to incorporate the use of directional antennas in its broadband implementation. This equipment is necessary to support the link budget (gain and discrimination) under any broadband deployment scenario, and is not being implemented to facilitate sharing. Importantly, the use of directional antennas will not overcome the interference problems inherent in any band sharing arrangement.

¹⁵ The scenario described by the FCC (two overlapping 2.5 MHz licenses) would result in a spectrum overlap of 40%. If a guard band of 125 kHz is afforded on either end of the band – a requirement noted by both Qualcomm and Flarion, the resulting overlap would be 60%. See section II, above.

heights of the two base station antennas in feet. Base station heights can range from 40 to 240 feet, corresponding to a radio horizon (d_{\min}) of about 18 to 44 miles. Areas near major airports tend to be built-up, requiring base station heights at the higher end of the range to be able to “see” aircraft at low elevation angles.

If the Commission were to adopt a reverse-banding arrangement for the ATG service, ground stations would have to be separated by forty miles or more to avoid harmful interference. Such a requirement would be impractical. In order to provide adequate service to ATG customers, including service from takeoff to landing, service providers must construct ground stations within close proximity of airports. Since harmful interference between ATG base stations would preclude the provision of service entirely, and not simply result in a lower quality of service, the spacing requirement described above effectively means that only one operator would be able to provide service at any given airport.

Boeing has also made two different proposals, the latest of which relies on spatial separations of ATG base stations to avoid interference.¹⁶ It indicated that a minimum separation of 102 miles would be required between base stations of competing providers.¹⁷ Boeing originally proposed that service providers be permitted to choose where to construct their base stations (as long as it is not within 102 miles of another provider’s base stations). However, in a later filing, it proposed that the FCC specify the location of base stations based on a pre-determined grid layout. As Airfone has previously explained,¹⁸ there are many shortcomings to this grid-based type of plan:

- With 102 mile spacing, there can be only one base station near an airport. (Indeed, in some situations, there could be only one near multiple airports – for example, Dulles, Reagan National, and Baltimore-Washington International airports are all within 102 miles of each other, as are John F. Kennedy airport, La Guardia, and Newark, or O’Hare and Midway.) Because a disproportionate percentage of service opportunities are near the airports, ATG providers with base stations located near airports are advantaged, due to better signal coverage of these high-density areas.

¹⁶ See Ex Parte Presentation of The Boeing Company, in response to *ATG NPRM*, filed Aug. 27, 2004 (“*Boeing Aug 27th Ex Parte*”).

¹⁷ *Id.*

¹⁸ See Ex Parte Presentation of Verizon Airfone, “*Response to Recent Boeing Filing*,” technical paper by Dr. Anthony A. Triolo, Telcordia Technologies, Inc., in response to *ATG NPRM*, filed Aug. 17, 2004 (“*Aug 17th Response to Boeing*”); see also Ex Parte of Verizon Airfone, presentations of Dr. Jay Padgett and Dr. Anthony Triolo of Telcordia Technologies, Inc., in response to *ATG NPRM*, filed Aug. 23, 2004 (“*Airfone Aug 23rd Ex Parte*”).

- This type of system limits capacity, since providers cannot perform cell splitting (sub dividing a larger cell into two smaller cells to provide capacity) without coordination among the providers.
- Centralized admission control software would be necessary to prevent one system from contributing large amounts of interference into another.
- This solution would not allow all operators to provide deck-to-deck service. Only one provider close to the airport would be able to provide service to the runway. Unless the same provider is close to every airport (a situation that would effectively pick the winner in a “competitive” environment), or unless airlines equip their planes with multiple systems, there will always be some flights for which “deck-to-deck” service is not available.
- It would require a highly regulated process for selecting and assigning specific ground station locations and the Commission would be responsible for administering this process.

2. Would directional antennas be required on the aircraft?

As previously noted, directional antennas are necessary to support broadband ATG deployment. However, even if directional antennas are used, cross-system interference will be experienced by both carriers under either of the spectrum sharing scenarios proposed by AirCell and Boeing.¹⁹ More significantly, without a mechanism for one provider to control the admission policy of the other, each provider would contribute an uncontrolled amount of interference into the other’s system.

AirCell proposes the use of highly specialized antennas to address concerns about harmful base-to-base interference with reverse-banding. Specifically, AirCell proposes to make use of ground station antennas with an elevation gain that would be required to roll off by 25 dB within an elevation angle change of only 1°. ²⁰ As Airfone has already demonstrated, this would not be practical from the perspectives of both an antenna design and antenna alignment.²¹

Boeing’s original proposal relied on the use of complex adaptive beam antennas. Airfone has already demonstrated that the use of such antennas is not practical or economical.²² Boeing’s latest proposal avoids the use of such complex antennas, but relies on ground station separations and an inflexible, pre-determined grid layout to avoid interference. As noted above, there are considerable shortcomings to such an approach.

¹⁹ See gen., *Airfone Jun 3rd Ex Parte*, *Aug 17th Response to AirCell*, *Aug 17th Response to Boeing*, *Airfone Aug 23rd Ex Parte*.

²⁰ See *Ex Parte Presentation of AirCell*, in response to ATG NPRM, filed Jun. 29, 2004 (“*AirCell Jun 29th Ex Parte*”); *Aug 17th Response to AirCell*.

²¹ *Aug 17th Response to AirCell* at 5-6; *Airfone Aug 23rd Ex Parte*.

²² *Airfone Jun 3rd Ex Parte* at 54-61.

3. Would tracking software be required to enable each service provider to know what the other service provider is doing?

In order to prevent debilitating amounts of interference from one system to the other, a centralized tracking and admission control system would be required to coordinate the number of users that could be present within each system at any point in time over the entire United States. In a typical single-system scenario, the Mobile Switching Center (MSC) can control which users are admitted into the system so as to keep the total noise rise in each cell (from both in-cell and out-of-cell users) to an acceptable level.

With two autonomous overlapping systems operating simultaneously, a centralized MSC that is common to both systems would be needed to prevent one system from interfering too heavily with the other. There are currently no off-the-shelf systems that can be used to control equipment belonging to two competing providers. Additionally, the problem of optimizing admissions for two competing providers covering the same space, subject to some “fairness” criteria, is a research problem that may require considerable time and effort to solve.

4. Are there limits on what modulation schemes could be employed? Can CDMA or OFDM be employed under any of the three scenarios? Can two CDMA or two OFDM systems share the spectrum on an overlapping basis? Can a CDMA system and an OFDM system share the spectrum on an overlapping basis?

We are not aware of any limitations regarding the technologies that could be deployed under Scenarios #1 and #3.²³ Both would support either CDMA or OFDM subject to a licensing scheme that would provide adequate guard bands, as described above. As we have noted throughout this paper, and in previous submissions to the Commission, there is a substantial risk of interference if two overlapping systems are permitted to operate. To date, our analysis has focused on two overlapping CDMA systems. The other cases (CDMA/OFDM and OFDM/OFDM) have not been as thoroughly analyzed. However, based on our understanding of the technology and discussions with technology developers, it is highly unlikely that the prospects for sharing between a CDMA system and an OFDM system, or between two OFDM systems, will be any more promising than sharing between two CDMA systems.

5. Would reverse banding be required?

AirCell proposed reverse-banding (or cross-duplexing) in its March 10, 2004 submission to the Commission, and its spectrum-sharing proposal relies entirely on a reverse-banding arrangement. In support of its proposal, it provided data regarding simulations for two reverse-banded CDMA 1xEV-DO systems based on a very low

²³ Under Scenario #1, CDMA or OFDM could be deployed in block A but neither could be deployed in block B.

aircraft transmit power. However, the use of such low power transmissions will not support broadband services, nor will such transmissions be robust in the face of non-ideal link path loss. As we have previously demonstrated, if aircraft transmit power is increased to more realistic levels, excessive aircraft-to-aircraft interference would occur, degrading the average forward link data rate and causing outages.²⁴ Moreover, reverse-banded aircraft will be especially susceptible to interference from the AN/SPS-49 Naval Air Search Radars.²⁵ Finally, reverse-banded operation will result in base-to-base interference near airports, which in effect will limit coverage of areas near airports to a single provider. For these reasons, reverse banding should not be permitted. As a result, AirCell's proposal cannot be supported.

6. Would cross polarization be required?

As an additional spectrum-sharing mechanism, AirCell has proposed using polarization isolation to separate the signals of two different systems.²⁶ However, there do not seem to be any measurement results, data, or even theoretical calculations showing the degree of polarization isolation that actually can be achieved in the ATG environment. While AirCell claims that empirical test data²⁷ supports the 12 dB isolation used in its simulations, a detailed review of the data revealed no basis for this claim.²⁸ However, even taking AirCell's results at face value, sharing via polarization isolation is unworkable due to the extremely high noise rise on the reverse link (at the base station receiver) in the airport scenarios.²⁹ If the polarization isolation is less than the 12 dB that AirCell assumed, the situation will be even worse.

7. Would special equipment be required on the aircraft or on the ground? If so, what are the costs of this equipment? Does the equipment employ "off-the-shelf" technology that is available today?

As previously noted, both AirCell's proposal and Boeing's initial proposal would require the use of complex antenna systems. This equipment is not available "off-the-shelf" today and is not likely to be practical or economical to build in the reasonable future.

²⁴ *Airfone Jun 3rd Ex Parte* at 50-51; *Aug 17th Response to AirCell* at 7-8; *Airfone Aug 23rd Ex Parte*.

²⁵ *Airfone Jun 3rd Ex Parte* at 53; *Airfone Aug 23rd Ex Parte*.

²⁶ See *Ex Parte* Presentation of AirCell, in response to *ATG NPRM*, filed Jun. 29, 2004 ("AirCell Jun 29th Ex Parte").

²⁷ See *Final Report of AirCell Flight Tests*, C.J. Hall and I. Kostanic, TEC Cellular, July 10-11, 1997.

²⁸ *Aug 17th Response to AirCell* at 8-15; *Airfone Aug 23rd Ex Parte*.

²⁹ *AirCell Jun 29th Ex Parte* at 52-56; *Airfone Aug 23rd Ex Parte*.

Additionally, some form of centralized admissions control software would be required, as previously discussed. This equipment is also not available as “off-the-shelf” technology.

8. What rules would the FCC need to adopt to facilitate sharing?

As Verizon has explained in detail, band sharing is not possible without resulting in harmful, and in some cases debilitating interference. However, if the Commission were nevertheless to adopt either of the Boeing or AirCell proposals, there are a number of rules that would be required to facilitate sharing of the band. As generally noted elsewhere, while necessary to reduce harmful interference, none of these rules would be desirable.

- If a reverse-banding scheme were adopted, a minimum separation between base stations would be required for spectrally-overlapping providers, and base station locations would need to be managed. This would put the manager in the position of effectively picking winners and losers among providers. If the same provider is near all airports, other providers would find it difficult to compete. If the central manager attempts to make sure that each provider is near some airports and distant from others, then the manager has essentially dictated which provider will serve which airlines (assuming the airlines will want to use the provider with towers close to their major hubs). In addition, in this situation, all providers will have poor service in some locations, which would provide Boeing's Connexion service an advantage in competing for airlines. Moreover, as mentioned above, “deck-to-deck” service would be impossible for many flights.
- If reverse-banding were employed, aircraft transmit power would need to be limited to avoid interference. Such a limit would necessarily impact the data rates delivered to customers, and could effectively preclude the delivery of broadband ATG services.
- Crossed-polarization would require some regulation to enforce polarization purity. Since polarization is being used here to separate the competing (interfering) signals, a polarization-isolation requirement is analogous to a spectral roll-off mask for adjacent-frequency systems. There therefore needs to be a limit on polarization “leakage”. The appropriate limit, as well as measurement and enforcement mechanisms would need to be developed.
- Crossed polarization would also require a real-time coordination mechanism (a cross-network admission control system) for controlling excessive interference into the other system's base stations in high-density environments.
- In schemes requiring a fixed grid of base stations, there would need to be some mechanism for administering or regulating changes in the grid required by cell splitting, driven by increased demand. This mechanism would need to strike a balance between the need for higher capacity (higher cost, higher density) grids by larger providers and the need for lower cost (lower capacity,

lower density) grids by smaller providers. This balance may be difficult to maintain, since limiting the grid density to the lower end limits the growth of the larger provider and allowing the grid to expand to higher density may prove prohibitively expensive for the smaller provider. In addition, the other problems with administration described in the first bullet, would be present in this situation as well.

9. How much coordination would be required between the two ATG licensees?

There would need to be considerable coordination. With the Boeing proposal and the AirCell reverse-banding proposal, base station locations would need to be carefully coordinated. With the AirCell cross-polarization proposal, admission control and handoff in high density areas would need to somehow be jointly managed by the two licensees to avoid excessive noise rise (power overload) at the base station receivers.

V. Impact on Future Growth and Service Evolution

In general, spectral overlap will complicate both technology evolution and the ability to increase infrastructure density to satisfy increasing demand. Unless the rules mandate a specific technology, there is the possibility of two overlapping providers using two different technologies either initially or later. No one has analyzed scenarios involving overlapping of two different technologies, but the expectation is that the interference environment would be worse.

In the case of reverse-banding, technology growth involving increased aircraft transmit power will increase the aircraft-to-aircraft interference.

Increased demand will require denser base station placement, which is problematic for the Boeing proposal (fixed grid) as well as both AirCell proposals. The Boeing plan would limit future growth by preventing capacity increases through cell splitting due to the requirement of maintaining a minimum inter-system base station separation. In addition, since these proposals do not allow for deck-to-deck operation, providers with base stations far from airports would be limited in their ability to provide service on the runway. With reverse-banding, the base stations must be separated by a distance greater than the radio horizon, which depends on the base station antenna elevations. For 100-foot elevations, the required separation is 28 miles. If the elevations range from 40 to 240 feet, the required separation ranges from about 18 to 44 miles. With crossed polarization, the excessive noise rise at the base stations is a problem in high density areas, as noted above.

Scenarios #1 and #3 present the greatest potential for evolution of the service. The broadband provider would not have to coordinate with the other provider in order to offer improved service to the public. The broadband licensee would have considerable flexibility in the location of ground stations and in the modification of those stations through such simple techniques as increased sectorization. In short, schemes required to

support Scenario #2 and its variants would force the providers into an awkward lockstep arrangement that would not only impede innovation, but would limit the ability of the providers to respond to growing competitive pressure from satellite providers of broadband service that would not face the same constraints.

VI. Treatment of Incumbent Licensee

Verizon Airfone has legal and equitable rights as the only qualified licensee providing in-flight services to the public. As described in the attached legal memorandum, the Commission cannot lawfully take actions that undermine those rights or the existing services provided to Airfone's customers.³⁰ When considering ATG spectrum allocation alternatives, the Commission must account for Verizon Airfone's rights as an incumbent operator in the band.

The various licensing scenarios being considered by the FCC do not appear to fully consider Airfone's incumbency rights. In particular, Scenario #2 does not describe how Airfone's rights would be protected if the entire band is licensed to two new licensees. Indeed, the evidence placed into the record regarding the potential for interference suggests that the Commission would not be able to provide such protection. Scenario #1 does appear to contemplate the protection of Airfone's existing service by moving it to block B, while using the A block for a new broadband service. However, the issuance of a new license in the B block would cause significant interference and should not be pursued for as long as Airfone continues to provide its current narrowband service.

VII. Conclusion

The establishment by the Commission of new rules and policies to promote the development of broadband ATG services in the 800 MHz band is highly desirable. However, the adoption of a licensing regime that requires band-sharing will create a significant potential for interference and frustrate this important objective. Conversely, if the Commission were to adopt either of the exclusive licensing scenarios under consideration by the Staff (modified to include appropriate guard bands), then a feasible broadband service is achievable. In fact, the data provided in this report demonstrates that an exclusive licensing regime is imperative to the successful delivery of a high quality broadband ATG service to consumers. We urge the Commission to adopt such an approach, and in doing so, to fully protect Airfone's existing narrowband ATG service.

³⁰ *“Verizon Airfone Has Legal And Equitable Rights As The Only Qualified Licensee Providing In-Flight Services To The Public,”* legal memorandum prepared by Wiley Rein & Fielding, Counsel to Verizon Airfone, Sep. 9, 2004.